CRES: Integrating Science & Management in the Caribbean
A Cooperative Agreement between the University of Puerto Rico (UPR) and NOAA's National Centers for Coastal Ocean Science (NCCOS)

ARTICLE I – BACKGROUND AND OBJECTIVES

The integrity of coral reefs is threatened by numerous anthropogenic and natural stresses including sediments, nutrient enrichment, climate change (bleaching), over harvesting, and storms. For instance, coral diseases are emerging as a significant cause of reef degradation in the Caribbean. Compared to other marine ecosystems, coral reefs may be particularly vulnerable to watershed-based stresses related to coastal development because coral reefs are usually best developed "beyond the influence of continental sediments" and flourish as 'closed systems' based on the internal recycling of nutrients. Over harvesting may also be particularly deleterious because the high biodiversity of coral reefs may be highly dependent upon complex biological interactions involving predation, herbivory, and competition. Reefs can also be indirectly affected via stresses to their associated mangrove and seagrasss communities because many keystone reef species use these adjacent habitats for recruitment and nursery areas. In addition to the separate effects of various stressors, synergistic interactions among stressors can further enhance adverse effects. For instance, the resiliency of some reefs to nutrient inputs may be compromised by over harvesting of the grazers that control frondose macroalgae that, in turn, can out-compete corals.

In response to the continued decline of coral reef ecosystem health, a 5-year research program funded through NOAA's Coastal Ocean Program (COP) has been developed to define and understand causes and effects of reef degradation, and provide managers information and tools to aid in reversing the degradation of US Caribbean reef ecosystems. This integrated multidisciplinary team, lead by scientists at the University of Puerto Rico, is based on existing collaborations (UPRM-UPRRP, UPRM-NOS-NMFS, USGS-NOS), and builds upon these and existing data extending over several decades and across the region. The overall strategic assessment will address the four major research focus areas defined in the Request for Proposals: 1) Relationships between watershed activities and coral reefs, 2) Causes of ecological stress, 3) Coral reef ecosystem integrity, and 4) Evaluation and linkages of marine protected areas. Our research counts on comparative studies among the sites (St. John, USVI; La Parguera and Culebra, Puerto Rico) to assess processes under different conditions and levels of stress, including multiple comparisons of MPAs with respect to biological and socio-economic processes. Items outlined in statement of work below describe NCCOS's proposed tasks in the overall CRES collaboration effort. Tasks fall under 4 major categories, including: 1) Coupling Species and Habitat, 2) Economic Coupling, 3) Coral disease, and 4) Database management.

ARTICLE II – STATEMENT OF WORK FY05

COUPLING SPECIES AND HABITAT (FY05 $115,000 of $510,000 – see budget table)

OBJECTIVES

NCCOS's contribution to the overall assessment will focus on three questions:

1) How do species' habitat utilization patterns differ at sites with varying states of habitat structure and reef degradation?
2) How do species' habitat utilization patterns differ inside and outside a Marine Protected Area (MPA)?
3) What role do fish species take in transporting energy between habitats?

METHODS

Questions 1 & 2:
To evaluate species' habitat utilization patterns, sampling locations are randomly chosen over hard-bottom habitats throughout St. John and southwestern Puerto Rico. This random selection ensures statements made are applicable over the entire region of interest. Additional sites are selected inside and outside the recently created Virgin Islands Coral Reef National Monument, an MPA south of St. John. The hard-bottom regions have been previously delineated and geo-referenced in a series of benthic habitat maps (NOAA 2001) and all site selection is done using ArcView GIS software.

GPS is utilized in the field to navigate to the preselected stations. Once there, two divers are deployed. One diver censuses the fish species along a 25 X 4 m transect. All fish are identified to the lowest taxonomic level possible, enumerated, and sized into 5 cm size class bins. The second diver collects detailed habitat information within 5 quadrats at randomly selected locations along the transect line. Information gathered includes percent coverage of abiotic parameters (rubble, sand, reef), biotic parameters (coral, algae, sponges), and rugosity. The methodology implemented to address question 2 varies in that the two divers both survey fish populations, one along a transect as before while the other conducts a stationary 7.5 m radius point-count. The surveyable area for this component of the study is in deeper water (~20-30 m). Due to limitations imposed by diving restrictions only coarse scale habitat information is collected and only over the area of the point-count.

Habitat data is analyzed to determine which of a suite of variables best quantifies the state of reef degradation. These variables are then related to metrics of fish community structure to determine how the state of reef health influences fish communities throughout the study region. Data is further explored to determine if patterns of fish habitat utilization differ within and outside of the MPA.

Question 3:
To evaluate the role fish species take in energy transport between habitats, passive fishing gears were deployed to capture adult and sub-adult fishes at habitat boundaries during migration movements associated with foraging. Sampling locations were again chosen utilizing the habitat maps (NOAA 2001) which were stratified into four habitat boundary classes: seagrass/reef; seagrass/mangrove; seagrass/unconsolidated sediments; and mangrove/unconsolidated sediments; as well as three zones: lagoon; outer lagoon; and bank shelf. Within those strata, three replicate 100 m long gill nets were deployed randomly. Nets were set proximal and parallel to habitat edges such that fishes moving across these boundaries were captured. All nets were left overnight with soak times ranging from 12-14 hours. Fish movement was inferred by noting fish orientation in the net and gut contents were removed in the laboratory and preserved for identification. Gut contents were identified to the lowest possible taxonomic level and weighed.

RESULTS

Question 1:
For the project period to-date, CCMA scientists have conducted 217 visual fish and benthic habitat surveys at randomly selected hardbottom locations throughout southwestern Puerto Rico (Figure 1) and 144 surveys around St. John (Figure 2).

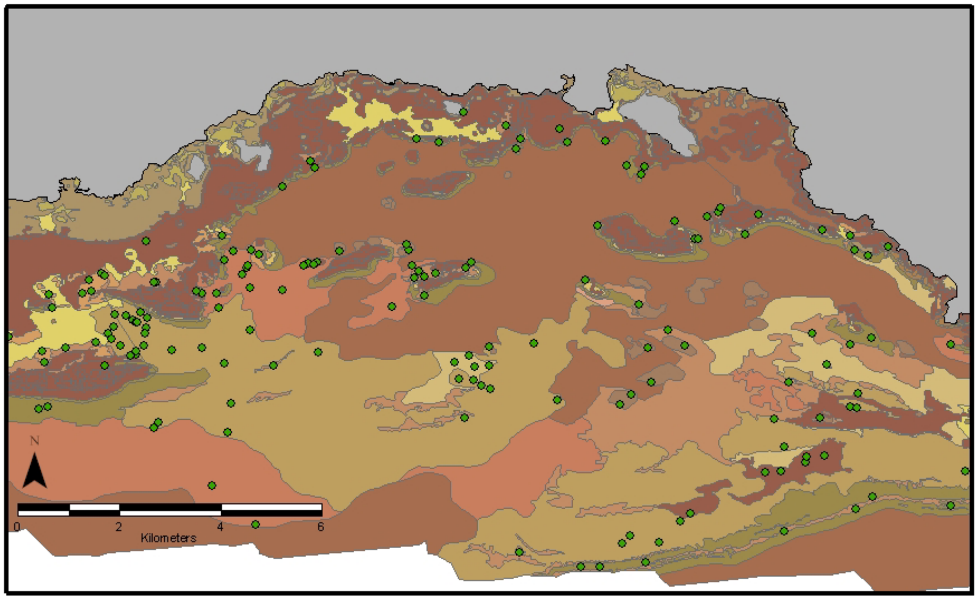

Figure 1. Distribution of sites sampled by NCCOS in southwestern, Puerto Rico.

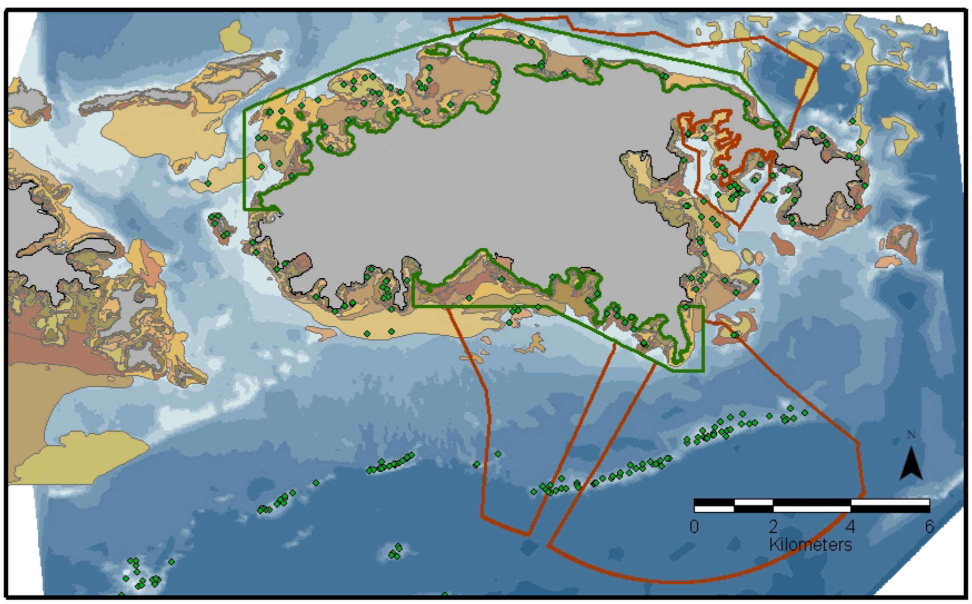

Figure 2. Distribution of sites sampled by NCCOS in St. John, Virgin Islands.

Benthic composition of reefs in Puerto Rico

Reefs at La Parguera, Puerto Rico generally were dominated by algae, with turf algae, crustose algae, and dead corals being the most abundant biotic cover (Figure 3). Macro algae on average accounted for about 16% of the observed benthic cover with *Dictyota* spp. being the most common followed by *Halimeda* spp. (29.4% and 25.4% of total macro algae cover respectively). Live coral cover was low, and averaged 7.6% of the areas sampled (Figure 3). Observed patterns in the relative abundance of algae, corals, and other benthic organisms were consistent among years, although some annual variation was observed (Figure 4). Annual variation in the relative abundance of benthic organism most likely resulted from differences in the types of benthic habitat sampled among years.

Patterns in the relative percent cover of benthic organisms were consistent also across reef types, with turf algae, crustose algae, and dead corals dominating all reef types, followed by macro algae, gorgonians, live corals, other benthic organisms, and sponges (Figure 5). The mean percent cover of live coral was highest on spur and groove reefs (16.9 ± 3.7 %) and lowest on reef rubble sites (0.7 ± 0.3 %). Macro algae was most abundant on reef rubble and patch reef substrates (20.7-22.6 ± 23.0-3.6%), but least prevalent on unidentified reefs (Figure 3). Mean gorgonian cover was highest on linear reefs (15.1 ± 1.9%); gorgonians generally were absent from reef rubble sites (0.5 ± 0.3%). Other benthic organisms – namely, anemones, tunicates, and zoanthids – were most common on linear reefs (2.4 ± 1.5% cover), and least abundant on reef rubble habitats (0.02 ± 0.02% cover). The percent cover of sponges was highest on unidentified reefs (5.7 ± 1.9%) and lowest on colonized bed rock substrates (1.4 ± 0.9%).

Twenty-four coral genera were identified from quadrat surveys on reefs in La Parguera (Figure 6). Several hard corals were not identified to the genus level but were classified as Scleractinia spp. Those corals accounted for 12.0 ± 2.6% of the benthic substrates surveyed. The most common identified coral genus was *Montastraea*, which had an average percent cover of 5.6 ± 0.7% (Figure 6). The genus *Mussa*, the most rarely identified coral genus was only observed at one site and had a percent cover of 0.04.

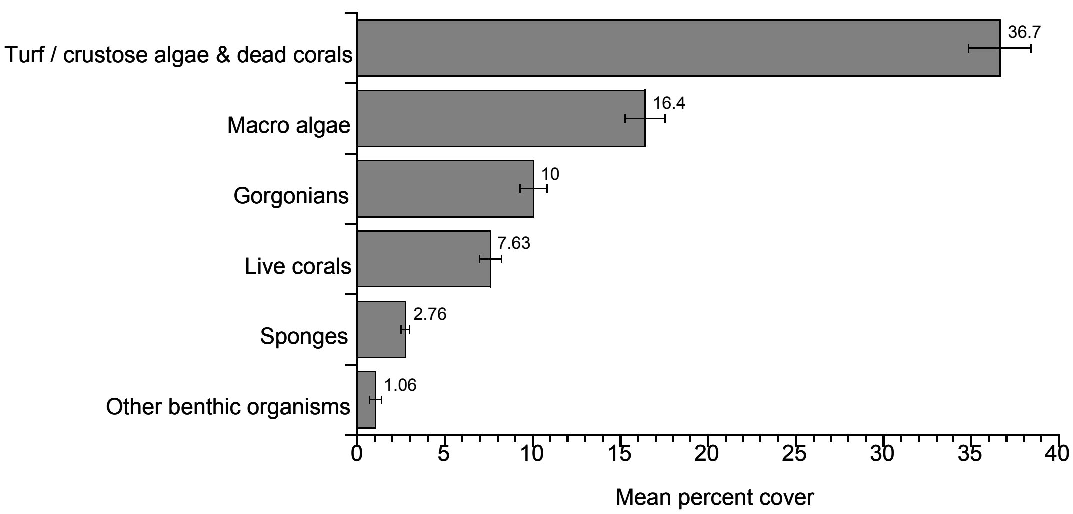

Figure 3. Mean total percent cover of benthic organisms on reefs at La Parguera, Puerto Rico. Bars represent the standard error of the mean. Data were collected from 187 sites surveyed between January 2001 and April 2004. The percent cover of benthic organisms was determined visually from five replicate 1-m^2 quadrat samples at each site. Other benthic organisms included anemones, tunicates, zoanthids, and tubeworms.

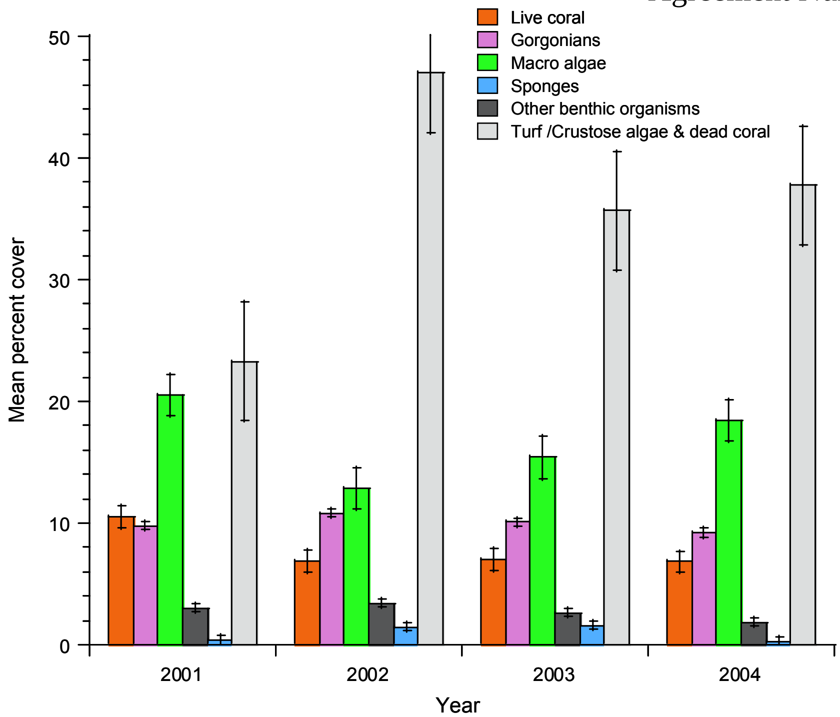

Figure 4. Annual percent cover of benthic organisms on reefs at La Parguera, Puerto Rico. Bars represent the standard error of the mean. Habitat types were classified based on digital benthic maps produced by NOAA for the region (NOAA 2001).

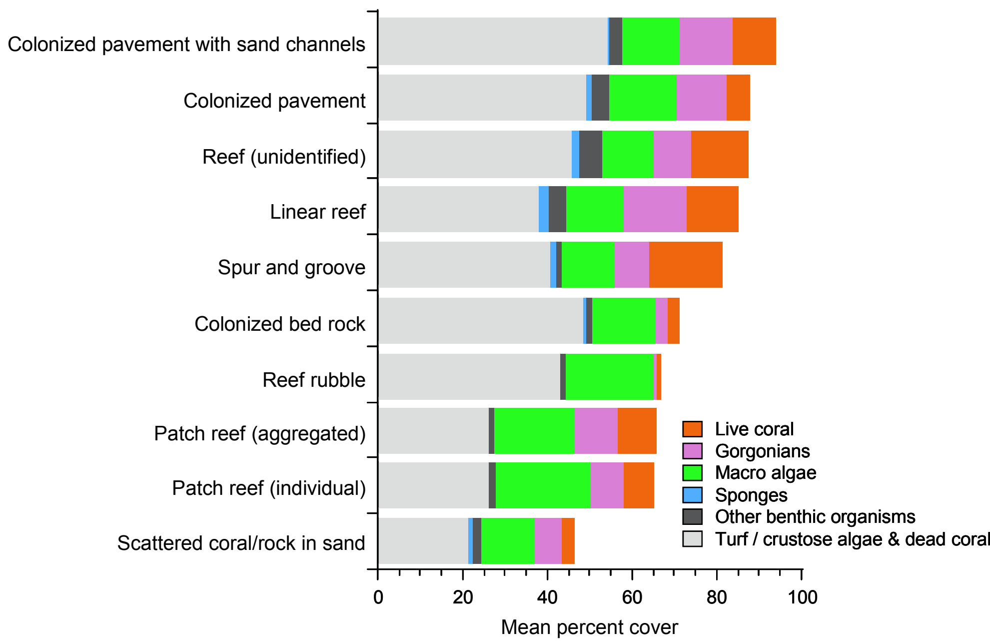

Figure 5. Mean percent cover of benthic organisms occurring in different reef habitats at La Parguera, Puerto Rico. Other benthic organisms included anemones, tunicates, zooanthids, and tubeworms. Habitat types were classified based on digital benthic maps produced by NOAA for the region (NOAA 2001).

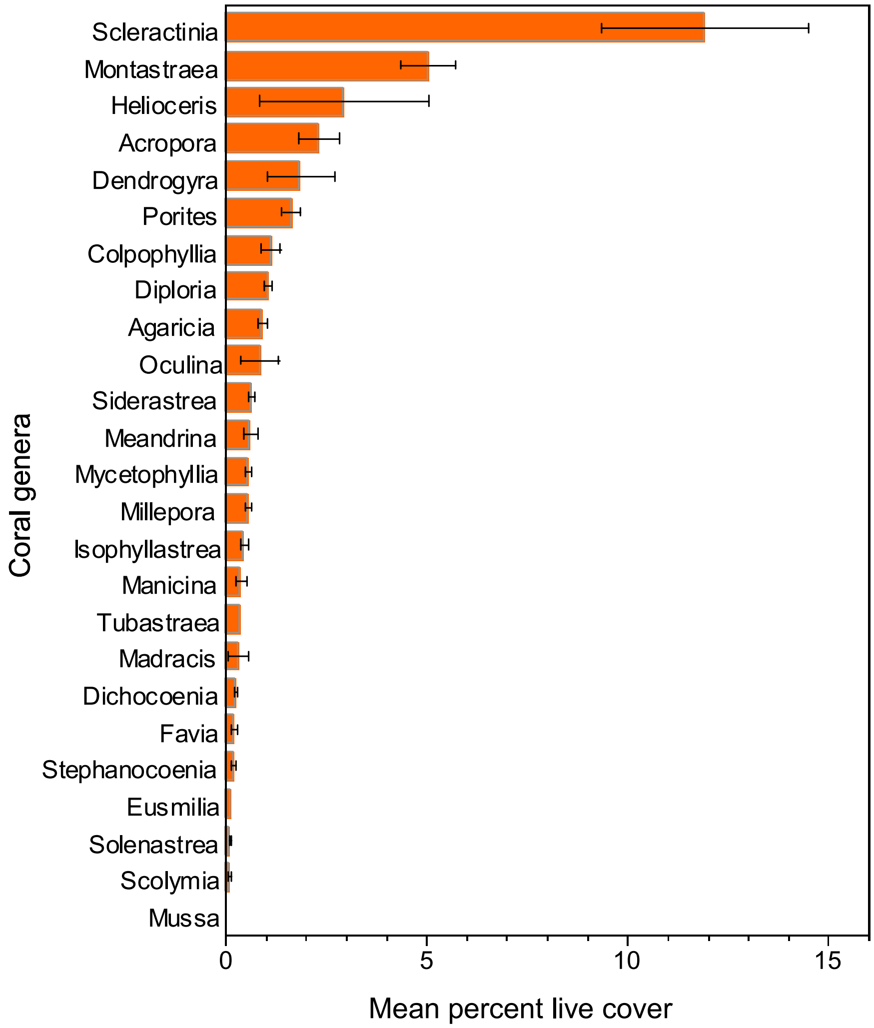

Figure 6. Mean percent live cover of coral genera on reefs occurring in La Parguera Puerto Rico. Bars represent the standard error of the mean. The percent cover of live coral was determined visually from five replicate 1-m^2 quadrats at each site. Scleratinia refers to hard corals that were not identified to the genus level.

Fish-habitat interactions in Puerto Rico

Coral reefs are the most speciose and exhibit highest average diversity among all of the habitats monitored. Benthic habitat data collected along each fish survey transect suggests that reef condition plays a large role in the observed results. There are several measurable parameters of overall reef health that appear to contribute to elevated reef fish abundance, richness, and diversity – among them are coral health (measured as percent live coral cover) and structural complexity (measured as rugosity). Figure 7 shows a comparison of all of these measures of fish community structure among reef sites classified by average percent live coral coverage. Each parameter exhibited a statistically significant relationship (log_{10} abundance, r^2=0.13, p<0.0035; richness, r^2=0.24, p<0.001; diversity, r^2=0.15, p<0.0013), with reef sites characterized by ≥6% live coral cover having significantly higher parameters of fish community structure. It is important to note that the average percent live coral coverage measured at 151 reef sites since 2002 is 3.22%, and has not changed significantly since 2002. Figure 8 shows the strong correlation between rugosity and associated reef fish communities, which indicates that reefs that are more structurally complex support more fish species (r^2=0.69, p<0001).

NCCOS coral reef ecosystem monitoring activities in southwestern Puerto Rico since 2002 indicate that parameters of fish community structure have not changed significantly over the past three years; however, several species of reef fishes have exhibited a decline in abundance (*i.e.*, Haemulid example). Community structure is significantly different among habitats within the seascape, and many species require one or more of these habitats for successful recruitment, growth, and reproductive success. As such, it is critical to consider the entire mosaic of habitats when managing the coral ecosystems in this region.

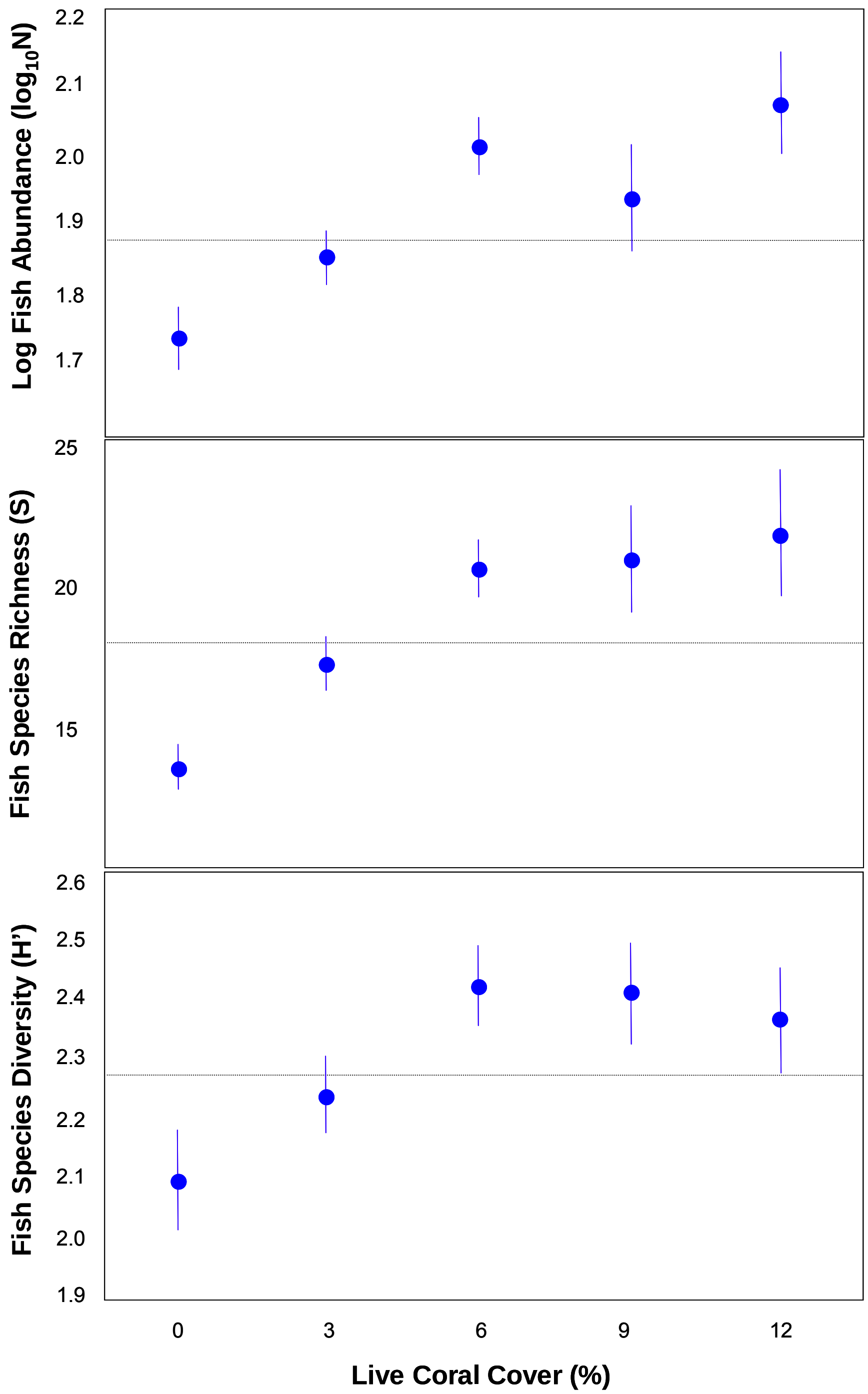

Figure 7. Comparison of log-transformed fish abundance, species richness, and diversity among reef sites classified by percent live coral cover.

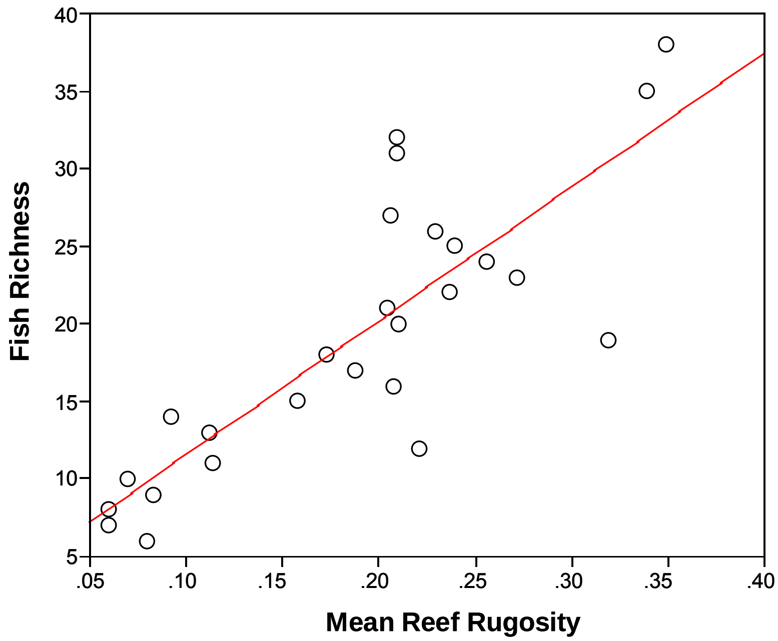

Figure 8. Results of regression between mean reef fish richness and mean reef rugosity.

Benthic composition of reefs in St. John

Reefs in St. John, USVI generally were dominated by algae, with turf algae, crustose algae, and dead corals being the most abundant biotic cover (Figure 9). Macro algae on average accounted for about 15% of the observed benthic cover. The most common macro algae was an unknown filamentous alga followed by the cyanobacteria, *Schizothrix* spp. and the red macro alga, *Asparagopsis* spp. (16.8%, 16.2% and 11.2% of total macro algae cover respectively). Live coral cover was low, and averaged 7.5% of the areas sampled (Figure 9). Observed patterns in the relative abundance of algae, corals, and other benthic organisms were consistent among years, although some annual variation was observed (Figure 10). Annual variation in the relative abundance of benthic organisms most likely resulted from differences in the types of benthic habitat sampled among years.

Patterns in the relative percent cover of benthic organisms were consistent across reef types, with turf algae, crustose algae, and dead corals dominating all reef types, followed macro algae, gorgonians, live corals, other benthic organisms, and sponges (Figure 11). The mean percent cover of live coral was highest on linear reefs (14.8 ± 2.4 %) and lowest on reef rubble sites (1.59 ± 0.6 %). Gorgonians were most abundant on aggregated patch reefs compared with other habitats but were absent from reef rubble sites. Macro algae cover was highly variable among habitats and had the highest cover on colonized bedrock and reef rubble habitats (Figure 11). The percent cover of sponges and other benthic organisms were relatively the same among benthic habitats.

Twenty-three coral genera were identified in St. John (Figure 12). The most common coral genus was *Montastraea*, which had an average percent cover of 3.92 ± 0.96% (Figure 12). *Caryophyllia* was the most rarely identified coral genus and had a percent cover of 0.45%.

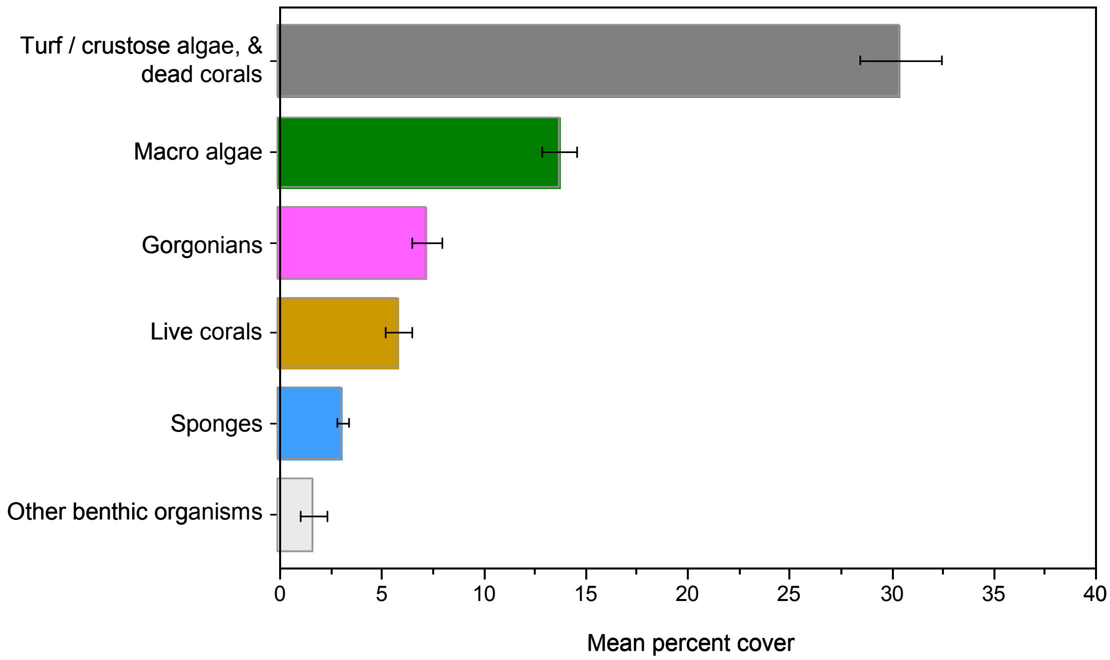

Figure 9. Mean percent cover of six groups of benthic organisms on reefs in St. John. Bars represent the standard error of the mean.

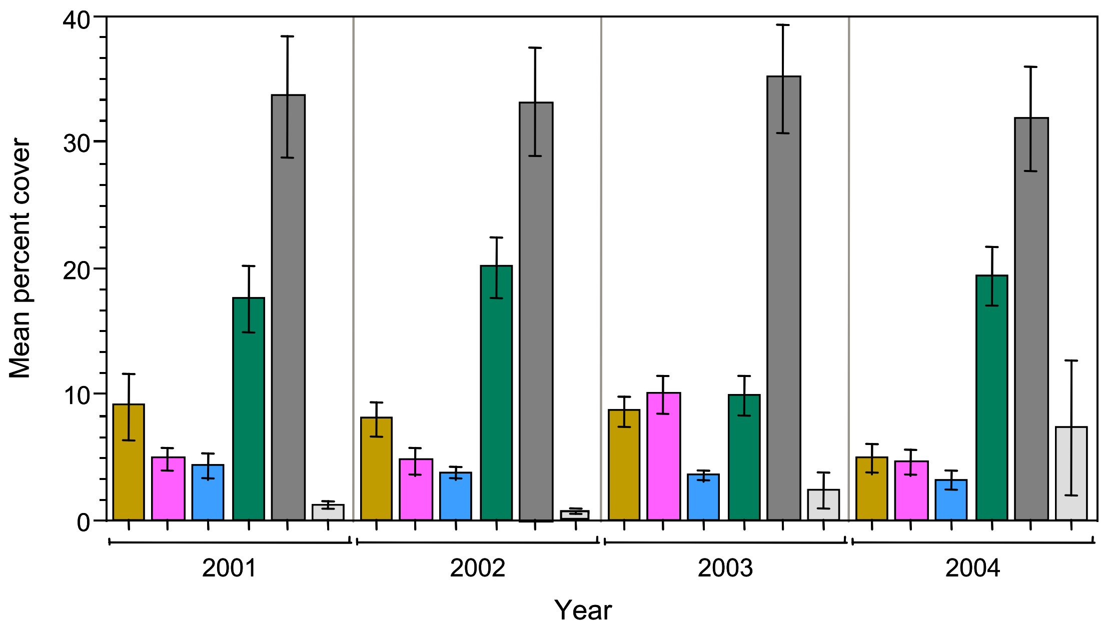

Figure 10. Annual percent cover of benthic organisms on reefs St. John, USVI. Bars represent the standard error of the mean. Habitat types were classified based on digital benthic maps (NOAA 2001).

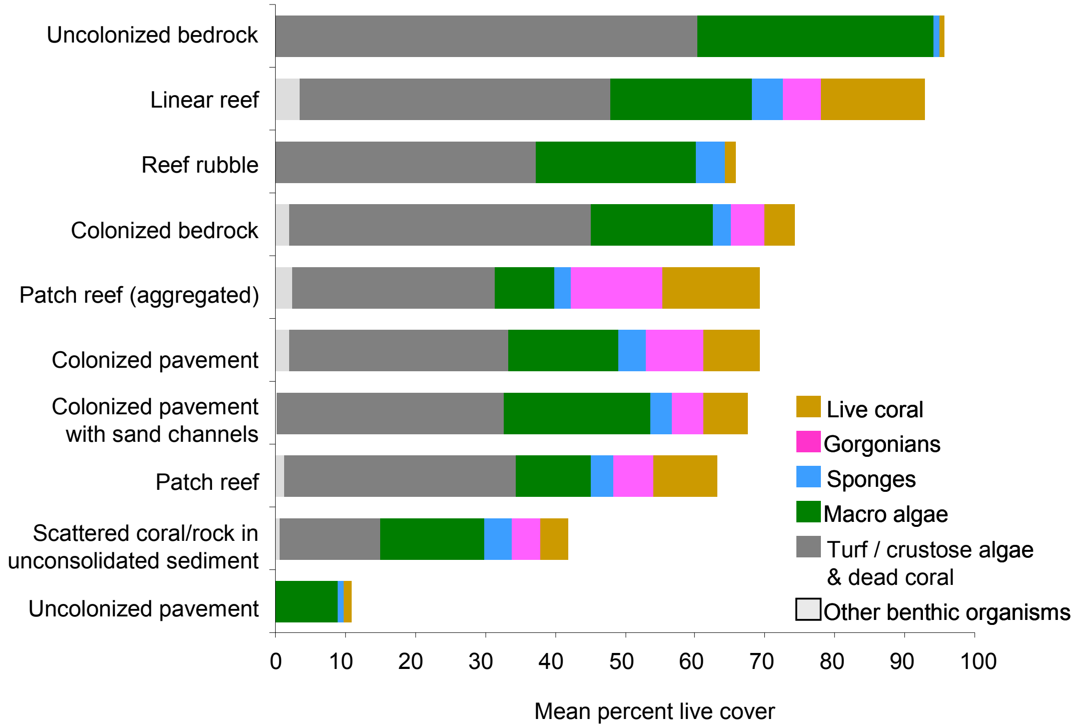

Figure 11. Mean percent cover of benthic organisms occurring in different reef habitats in St. John. Other benthic organisms included anemones, tunicates, zooanthids, and tubeworms. Habitat types were classified based on digital benthic maps (NOAA 2001).

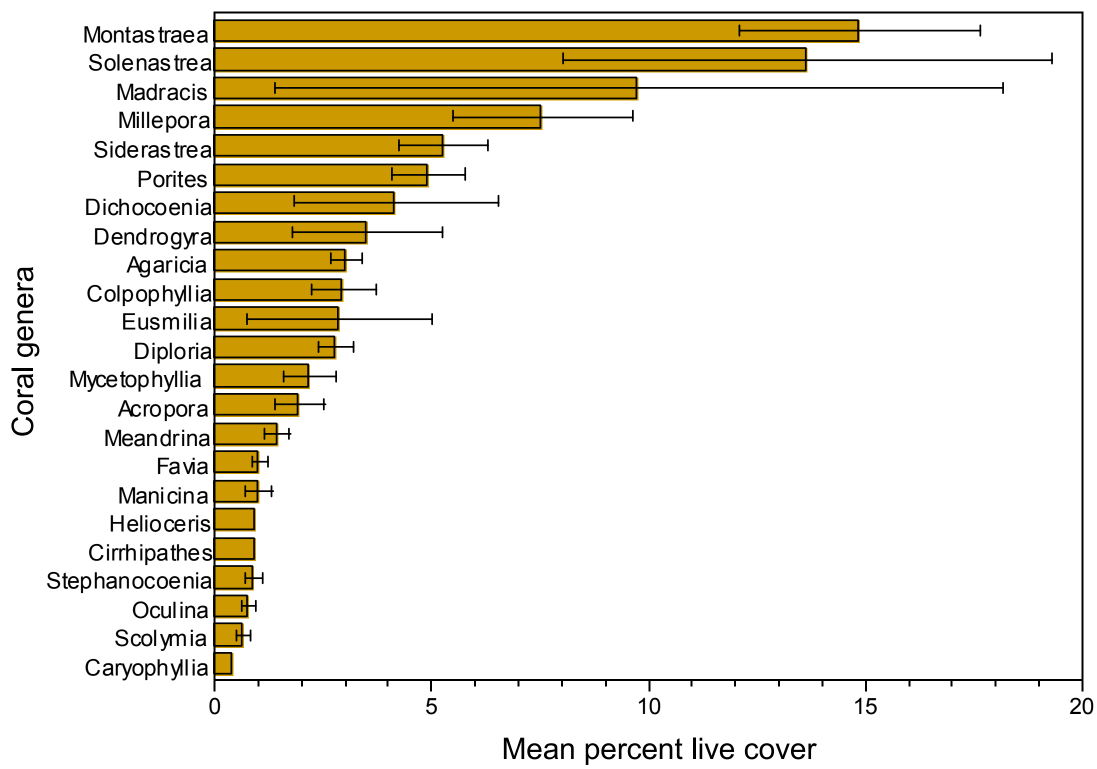

Figure 12. Mean percent live cover of coral genera on reefs occurring on reefs in St. John, USVI. Bars represent the standard error of the mean. The percent cover of live coral was determined visually from five replicate 1-m^2 quadrats at each site.

Fish-habitat interactions in St. John, USVI

Again, data from NCCOS' reef fish monitoring also suggested that parameters of fish community structure on reefs in St. John were influenced by coral health (percent live coral cover) and structural complexity (rugosity). Total fish abundance and fish species richness increased, whereas fish diversity decreased significantly with an increase in live coral cover and reef rugosity (Figures 13 and 14). The decrease in fish diversity as percent live coral cover increased may have resulted from an overwhelming abundance of a few species (e.g., *Chromis* spp.) at sites with high coral coverage, which could have reduced the overall fish diversity of those sites compared with sites having lover abundance of corals. It is important to note that percent live coral cover was significantly correlated with reef rugosity (r^2 = 0.37, P = 0.00). Additionally, the overall average percent live coral coverage measured at 144 reef sites in St. John was 7.5% and has not changed significantly since 2001 (r^2 = 0.02, P = 0.09). Thus, parameters of fish community structure and reef health in St. John were spatially rather than temporally correlated, such that healthier reefs (i.e. reefs with more live coral) supported greater numbers of fish individuals and species than did less healthy reefs.

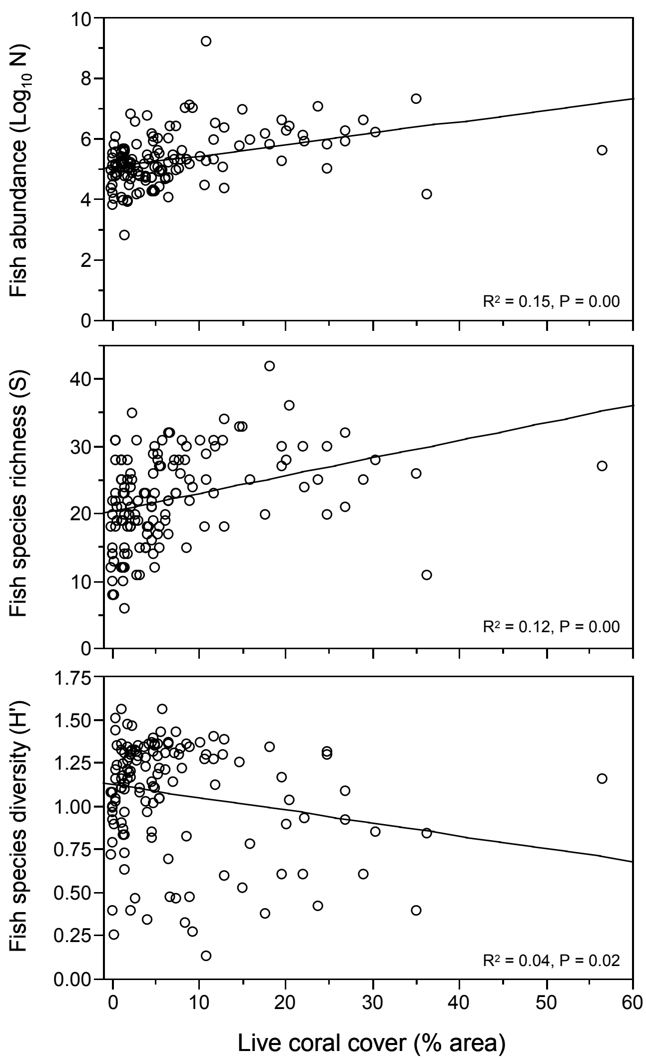

Figure 13. Comparison of fish abundance, species richness, and diversity among reef sites classified by coral abundance, st. John, USVI.

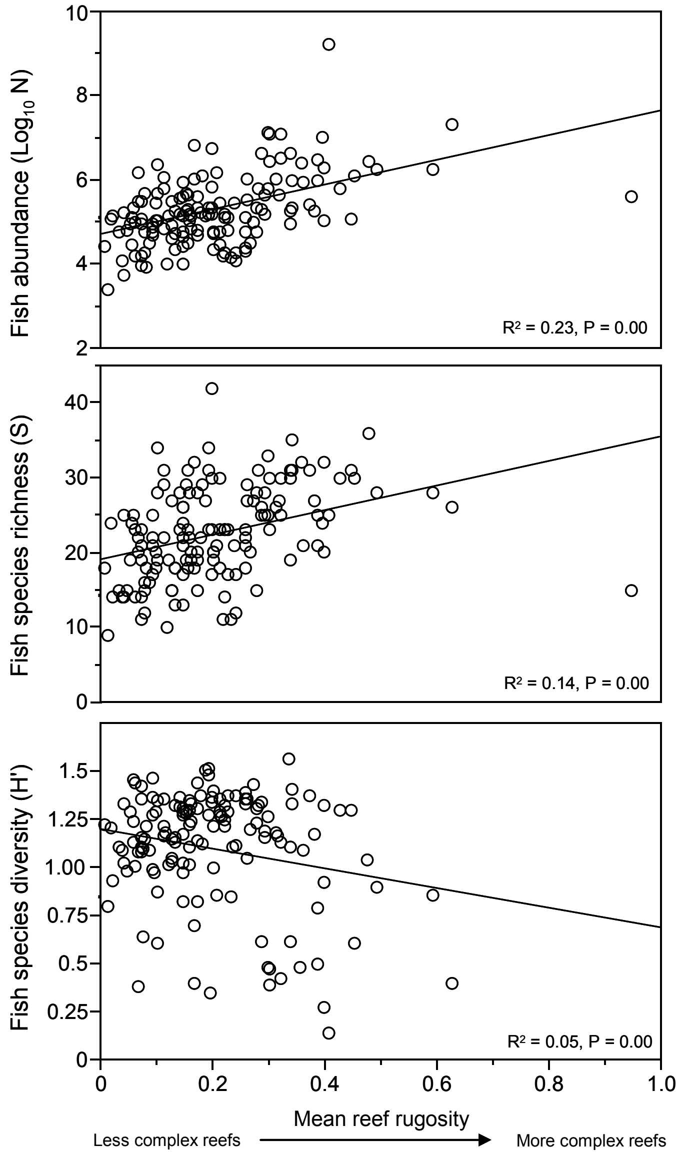

Figure 14. Results of regression of mean fish species abundance, richness, and diversity against mean reef rugosity for reefs in St. John, USVI.

Question 2:

A total of 129 sites were sampled as part of the study to assess fish habitat utilization patterns inside and outside of the MPA. Percent coverage of habitat variables was arcsine squareroot transformed for statistical analysis. Means and standard deviations were computed for selected variables and compared using a T-test for differences inside versus outside the MPA (Table 1). There was no significant difference (p>0.05) in the depth at which fish censuses were conducted, nor in the percentage of hardbottom or sand found within vs. outside the monument. Specific biotic components of the benthic community (gorgonians, macroalgae) also showed no significant differences (p>0.05) within or outside the boundaries of the monument; however, both the estimated percent live coral cover and habitat complexity (e.g., rugosity) was significantly greater outside the monument.

Habitat Characteristic	Inside MMSR	Outside MMSR	Percent Difference	Student's T-test	P value	Power
Abiotic						
Depth	82.65 (8.04)	83.39 (5.16)	<1.00	0.41	0.679	0.07
Rugosity	1.26 (0.12)	2.09 (0.12)	39.71	4.83	<0.001*	0.99
Percent Hardbottom	87.13 (11.75)	81.75 (11.27)	6.17	1.64	0.106	0.36
Percent Sand	11.09 (12.10)	12.37 (10.94)	10.35	0.45	0.652	0.07
Biotic						
Percent Live Coral Cover	6.61 (9.72)	21.74 (19.07)	69.60	4.11	<0.001*	0.98
Percent Gorgonians	15.95 (13.30)	15.42 (9.86)	3.32	0.12	0.894	0.05
Percent Macroalgae	41.90 (24.88)	35.11 (22.85)	16.21	0.76	0.450	0.11

Table 1. Comparison of benthic habitat characteristics inside and outside VICRNM along the midshelf reef south of St. John.

The next step was to determine if there were differences in the fish communities between locations that might be related to those habitat differences. The communities were categorized into trophic guilds and examined for differences in abundance and biomass inside and outside the MPA. Herbivore ($p<0.001$) and planktivore ($p<0.001$) numerical abundance was greater outside the monument, while mobile invertebrate feeder abundance was significantly greater ($p<0.01$) inside the monument (Figure 15). The only significant difference in estimated biomass between strata was in the planktivore ($p<.01$) trophic guild (Figure 16).

Comparisons were also made of abundance values of commercially important grouper species. Large groupers were uncommon throughout the study area. Coney (*Cephalopholis fulvus*) abundance was slightly greater outside the monument (58%), while the red hind (*Epinephelus guttatus*) was found in equal numbers. The largest difference in grouper abundance was observed for the graysby (*Cephalopholis cruentatus*) with 86% observed outside the monument. Higher coral cover and structural habitat complexity may explain this observed difference. Two tiger groupers (*Mycteroperca tigris*) were observed outside the monument.

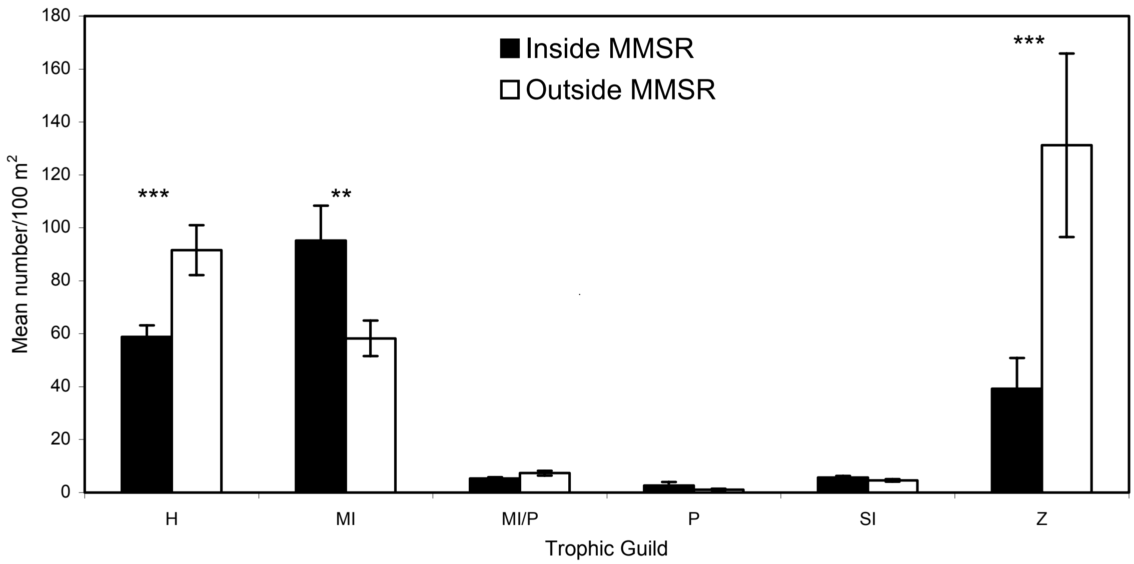

Figure 15. Trophic composition of fishes by number. (Values ln(x+1) transformed for statistical analysis). H – herbivores, MI – mobile invertebrate feeders, MI/P – mobile invertebrate/piscivore feeders, P – piscivores, SI – sessile invertebrate feeders, Z – planktivores. ** = $p<0.01$; *** = $p<0.001$

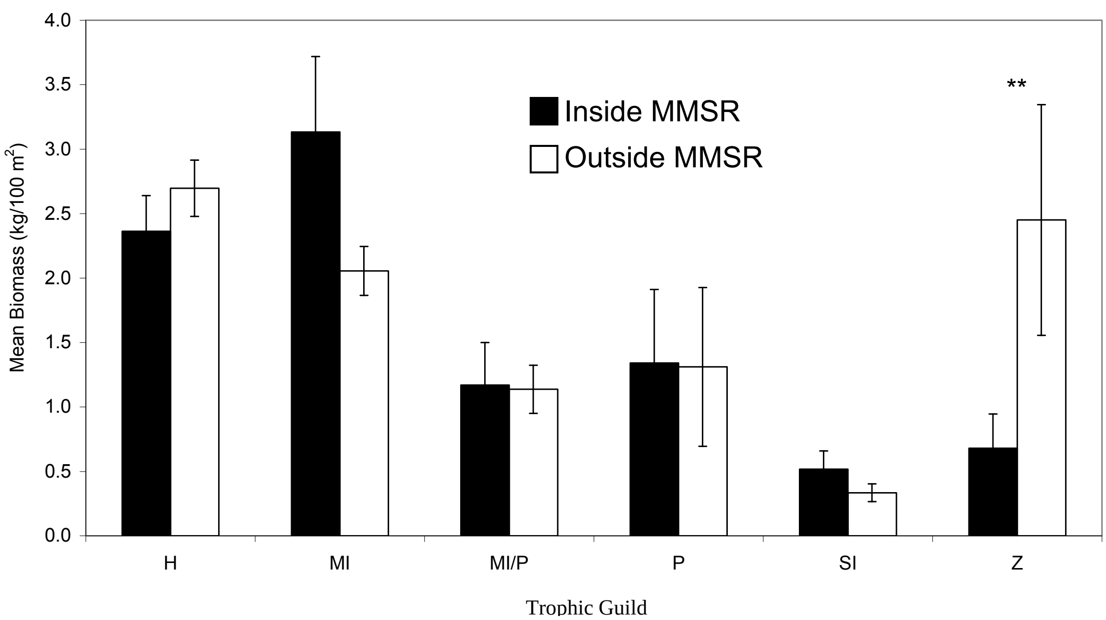

Figure 16. Trophic composition of fishes by weight. (Values ln(x+1) transformed for statistical analysis). H – herbivores, MI – mobile invertebrate feeders, MI/P – mobile invertebrate/piscivore feeders, P – piscivores, SI – sessile invertebrate feeders, Z – planktivores. ** = $p<0.01$

Question 3:

Through December 2002, 184 gill nets were deployed which captured 690 fishes comprising 72 species. There was no significant difference in fish abundance among the strata sampled (Figure 5) although correspondence analysis revealed significant patterns of species specific utilization patterns among the four habitat types sampled (seagrass, reef, unconsolidated sediments, and mangrove). Approximately 17% of stomachs extracted were empty. Of the identifiable gut contents, crabs were the most abundant prey item in terms of percent occurrence (Figure 6), while mollusca, algae/seagrass, fish, and other crustaceans yielded greater than 10% frequency of occurrence. Shrimp, polychaetes, and echinoderms were less common, with each having frequencies less than 6%.

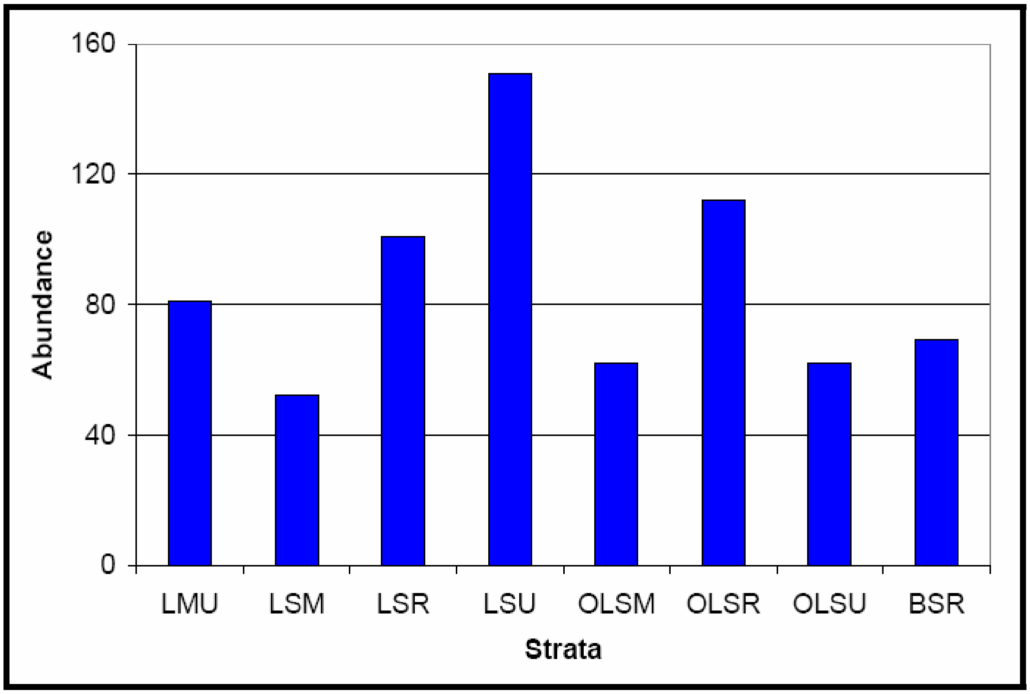

Figure 5. Fish abundance among 8 strata sampled with the La Parguera coral reef ecosystem.

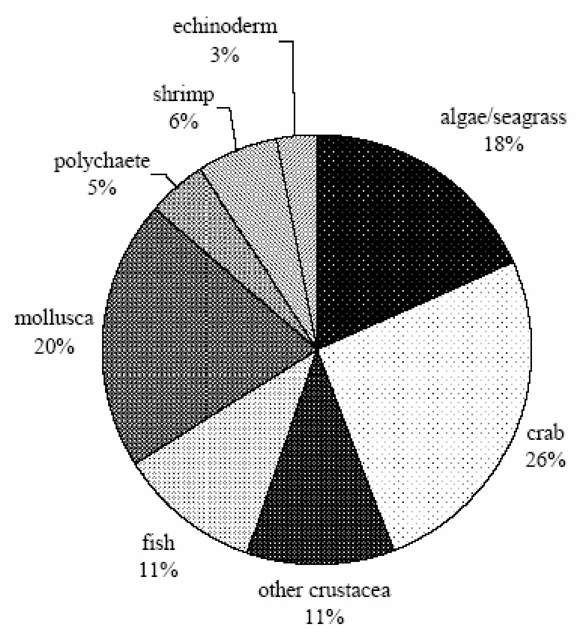

Figure 6. Frequency of occurrence of prey items found in stomach contents of fish captured in gill net samples.

RELATION TO OTHER RESEARCH COMPONENTS

The results of this particular project will be integrated with concurrent studies under the same proposal. Within the "Reef Processes" component of the proposal PIs are working on mark and recapture and acoustic tagging studies. These studies are designed to examine the patterns of movement of adult fish species and evaluate home range size. The energy flow work being conducted by NCCOS will allow interpretation of these movements. Furthermore, by utilizing the habitat utilization information gathered by NCCOS in conjunction with these other studies, proposed MPAs can be evaluated based on the health of their reefs and their size.

Work is also being conducted on the CRES grant to consider socioeconomic factors in the delineation of MPAs and to identify how best to include the public in the delineation process. In combination with the biological analyses this work will aid significantly in the evaluation of proposed MPAs.

All results obtained as part of this study will be made available to other PI's via the Database Management System as well as to other researchers via a website and peer-reviewed publications.

FY05 IMPLEMENTATION

During FY05 we will be sampling La Parguera on two separate trips spaced evenly throughout the year. A total of 84 additional hardbottom sites will be surveyed during this time. St. John will be sampled on only one occasion with 36 hardbottom sites being surveyed to address the question of the relationship between fish communities and reef health. An additional 72 sites will be surveyed specifically to address the question of habitat utilization differences inside vs. outside an MPA. During each sampling mission, per the protocol above, a transect fish count as well as corresponding habitat data will be collected. In St. John fish will also be censused employing the point-count census methodology. While the field component of the work necessary to address Question 3 has been completed, during the course of this Fiscal Year, we anticipate the development of a report analyzing the data collected to date and discussing the results.

DATABASE MANAGEMENT (FY05 $15,000 of $65,000 – see budget table)

OBJECTIVES

In order to integrate the results of the varying multi-disciplinary components that are a part of the CRES grant, a robust, centralized database management system (DBMS) is needed to store or provide access to all sub-project information/data and associated metadata in a consistent analytical framework. Additionally, a mechanism for sharing general project information and posting project descriptions will be required.

RESULTS

No data has been submitted for uploading to-date; however, a Program specific web-site has been developed to provide project updates and disseminate results. The website is currently being maintained by NCCOS and UPR but contains links to all home institutions of principal investigators. Contributions from only a few partners have been made to-date.

FY05 IMPLEMENTATION

Once data has been submitted or access to data provided, the database will be developed based upon the nature of the particular datasets. Furthermore, the DBMS will be made accessible to all members of the research team and the general public via the world wide web (NOAA's CoRIS website).

CORAL DISEASE (FY05 $116,000 of $300,000 – see budget table)

OBJECTIVES

The primary objectives of this project are :

- to conduct ecological and microbiological research on white plague, a disease that has affected almost all species of Caribbean corals and which has caused severe tissue loss in colonies of the major reef-building species, *Montastraea annularis* complex.
- to determine the microbes associated with white plague
- to find out if biomarkers are useful in identifying stresses that may be associated with disease
- to determine the genotypes of a sub-set of the healthy and diseased colonies selected for sampling.

METHODS

Several techniques will be used. A cellular diagnostic system will be used by collaborating NOAA scientists (Dr. Cheryl Woodley and others) to determine the cellular-physiological condition of healthy and diseased colonies of *Montastraea annularis* and identify possible stressors. For the genetic portion of the work, coral and microbial DNA will be amplified as well as bacterial ribosomal RNA coding sequences. Molecular methods will also be used to characterize the microbial populations associated with healthy and diseased colonies of *Montastraea annularis*.

RESULTS

An Interagency Agreement was established between NOAA and USGS. Preliminary work has been done at Tektite Reef to estimate the current prevalence of the disease, and photographs of colonies with white plague have been taken.

RELATION TO OTHER RESEARCH COMPONENTS

The proposed research is closely linked to work by Dr. Cheryl Woodley (see below). It also complements research in Puerto Rico that is being conducted under the CRES program by Dr. Ernesto Weil. Dr. Weil will be invited to St. John to examine the prevalence of white plague disease and to allow comparison with results from Puerto Rico. We will explore the possibility of having some samples from reefs in Puerto Rico analyzed by USGS scientist Dr. Bane Schill for microbial and genetic analysis, to compare with samples from St. John.

FY05 IMPLEMENTATION

This fiscal year we will be doing several pilot studies to help establish the most effective sampling design for the overall project. These will involve both laboratory and field efforts. Diseased and healthy portions of star coral (*Montastraea annularis)* will be collected for analysis of biomarkers using the cellular diagnostic system. USGS scientists will collect these samples or will provide field support for collection by scientists working with Dr. Cheryl Woodley (NOAA) and Dr. Craig Downs (Envirtue Biotechnologies). USGS scientists Dr. Bane Schill and Jim Murray will travel to St. John to collect samples of healthy and diseased portions of star coral for microbial and genetic analysis back at their laboratory at the USGS Science Center in West Virginia. In conjunction with monitoring of random video transects at 2-3 reefs off St. John this year, data will be collected on the number and species of coral with diseases one meter on either side of each transect. Individual coral colonies (most likely at Tektite Reef) will be selected for more detailed and more frequent monitoring.

Dr. Caroline Rogers will be responsible for making sure that all necessary National Park Service Research/Collecting Permits are obtained.

Dr. Cheryl Woodley and Dr. Caroline Rogers will be co-organizers of a special session on white plague and other “white diseases” at the Estuarine Research Federation’s annual meeting in October 2005. During this fiscal year they will be preparing for this special session (reviewing abstracts, selecting speakers, and preparing presentations).

ECONOMIC COUPLING (FY05 $5,000 of $35,000 – see budget table)

OBJECTIVES

Scientific findings will be integrated using a relational database and GIS technologies housed within an interdisciplinary predictive Decision Support System (DSS). The objective of developing the DSS is to couple ecological and socio-economic results so that managers can predict or assess the impact of a management or suite of management strategies within and outside MPA boundaries. Most importantly, the DSS will provide managers not only the study results in a user-friendly format, but a capability to conduct impact scenario assessments from implementation of various management strategies. The system will be formulated to address the overall goals of defining and understanding the causes of Caribbean coral reef ecosystem degradation and to stop or reverse the degradation based on findings of the integrated research program.

RESULTS

This work is set to begin this fiscal year.

FY05 IMPLEMENTATION

Preliminary meetings will be held to decide on the most appropriate manner in which results will be integrated.